

## SPECIFICATION

# Multilevel quadrature amplitude modulation system

A multilevel quadrature amplitude modulation system,  
being used in a multilevel quadrature amplitude modulating  
apparatus comprising:

a differential-rotation object encoder (1) for encoding digital signals in plural systems being entered so as to remove the phase ambiguity of regenerative carrier,

a digital/analog converter (2) for converting the output of said differential-rotation object encoder into an analog signal, and

a modulator (3) for modulating the carrier in quadrature amplitude by the output of said digital/analog converter, comprising:

a signal point layout converter (4) for expanding the interval of signal points closest to the boundary of each quadrant,

wherein the bit error rate is improved.

### 3. Detailed Description of the Invention

[Summary]

In a multilevel quadrature amplitude modulation system,

a signal point layout converter is inserted between a differential-rotation object encoder for removing phase ambiguity of regenerative carrier and a digital-to-analog converter, and the interval of signal points closest to the boundary of each quadrant is expanded, so that deterioration of bit error rate is improved.

[Industrial Field of Utilization]

The present invention relates to an improvement of multilevel quadrature amplitude modulation system used in digital microwave communications.

Recently, various digital microwave systems are realized, including the 64-level quadrature amplitude modulation system (hereinafter called 64QAM system), and to enhance the efficiency of use of frequency, there is a further multilevel trend, for example, 256QAM system.

The more advanced the multilevel trend, the severer is required the performance of the apparatus, and the apparatus is required, for example, to minimize the deterioration of bit error rate.

[Prior Art]

Fig. 3 is a block diagram of a conventional example, and Fig. 4 shows a signal point layout diagram of Fig. 3, both referring to the 256QAM system.

The numeral given beneath each point is data of second bit to fourth bit, and when the first bit numeral given in the upper right parentheses of each quadrant is added before the second bit, the corresponding data is obtained. For example, the data

at point A is 100 100, and when 11 at the upper right corner of the first quadrant is added, it actually shows 1100 1100.

Referring to Fig. 4, the operation in Fig. 3 is explained. First, in Fig. 3, the entered data of four bits and two systems (1ch, Qch) is given to the differential encoder 11 of the differential-rotation object encoder 1.

Herein, as disclosed in "Digital Microwave Communications" (Moriiji Kuwabara, pp. 106-107, published by Project Center, March 1, 1985), in order to demodulate the correct data without knowing the absolute phase of transmission signal, the information is not placed on the position of signal point, but the information is placed on the transition of position.

That is, the summation operation of  $y_i = x_i + y_{i-1}$  is converted by the differential encoder 11 into the original signal by differential operation of  $x_i = y_i - y_{i-1} \dots (x_i + y_{i-1}) - y_{i-1} = x_i$  in the reception side differential decoder (not shown), so that it is possible to demodulate without knowledge of absolute phase of the transmission signal.

Herein,  $y_i$  is the encoder output and  $x_i$  is the encoder input, and the summation operation and differential operation are paired operations, and both are combined and called differential conversion.

Consequently, the output of the differential encoder 11 is added further to the rotation object encoder 12, and, as shown in Fig. 12, the second-bit to fourth-bit codes are arranged so that equal codes of each quadrant may be at intervals of 90

degrees.

For example, in Fig. 4, signal point B of fourth quadrant and signal point B of first quadrant, and signal point C of first quadrant and signal point C of second quadrant are respectively at an interval of 90 degrees (except for the code of the first bit). Accordingly, when demodulating, if there is phase ambiguity of  $90 \times n$  degrees, such as 0, 90, 180 and 270 degrees in the phase of the reference carrier, no change occurs in the second to fourth bit, and the differential conversion may be done only on the first bit signal, and the signals of second to fourth bit are passed directly without being converted.

Herein,  $n$  is an integer.

When 1100 1100 is entered in the rotation object encoder 12, 1111 1111 is put out, and is converted into a maximum analog quantity in digital/analog converters 21, 22, and the carrier is modulated in quadrature amplitude in the modulator 3, and arranged at the position of point A.

Here, the input data are converted to analog amount corresponding to the respective positions of signal point layout diagram of Fig. 4, and disposed to positions as shown in Fig. 4, respectively.

[Problem that the Invention Is to Solve]

As shown in the signal point layout in Fig. 4, within a same quadrant, for example, if signal point D (000 010) of the lower three bits is mistaken to an adjacent bit 001 110, or 001 010, only one bit is wrong.

However, in the case of error over plural quadrants, a

multibit error occurs. For example, as shown in the column of "Number of errors when crossing quadrants" in Fig. 4, a maximum error of six bits may occur. This is a problem of deterioration of error rate.

[Means for Solving the Problem]

The problem is solved by the multilevel quadrature amplitude modulation system of the invention for improving the bit error rate, by disposing, as shown in Fig. 1, a signal point layout converter 4 in the multilevel quadrature amplitude modulating apparatus, and expanding the interval between the signals closest to the boundary of each quadrant.

[Operation of the Invention]

The invention has decreased the possibility of occurrence of error crossing over quadrants, by expanding the interval of signal points closest to the boundary of each quadrant.

That is, between a differential-rotation object encoder 1 and a digital/analog converter 2, a signal point layout converter 4 storing the signal point layout in Fig. 2, for example, a read-only memory is inserted, and the output of the rotation object encoder 12 is converted to the signal point layout in Fig. 2 and added to the digital/analog converter. As a result, the number of wrong signal points crossing quadrants is decreased, and the bit error rate is improved.

[Embodiment]

Fig. 1 is a block diagram of an embodiment of the invention, and Fig. 2 shows a signal point layout of Fig. 1, and the unit added in the embodiment of the invention is a signal point layout

converter 4.

Throughout the drawings, same reference numerals represent same components, and the 256QAM system is shown.

Referring now to Fig. 2 and Fig. 4, the operation in Fig. 1 is described below.

As shown in Fig. 1, the entered data of four bits and two systems (I<sub>ch</sub>, Q<sub>ch</sub>) is converted into a 2-level signal as shown in signal point layout in Fig. 4 by the differential-rotation object encoder 1, and is added to the signal point layout converter 4. The signal point layout converter is composed of, for example, a read-only memory, which stores the data for converting the signal point layout in Fig. 4 into the signal point layout in Fig. 2, and the corresponding data is read out according to the output of the rotation object encoder as the address, and is added to the digital/analog converter 2 to be converted to an analog quantity, and the carrier is modulated in quadrature amplitude in the modulator 3, so that the 256QAM wave having the signal point layout as shown in Fig. 2 is obtained. As a result, the bit error rate is improved.

[Effects of the Invention]

As described in detail herein, the interval between signal points closest to the boundary of each quadrant is expanded, and hence the deterioration of bit error rate is improved.

#### 4. Brief Description of the Drawings

Fig. 1 is a block diagram of an embodiment of the invention,

Fig. 2 is a signal point layout of Fig. 1,

Fig. 3 is a block diagram of a conventional example, and

Fig. 4 is a signal point layout of Fig. 3.

In the drawings,

1 is a differential-rotation object encoder,

2 is a digital/analog converter,

3 is a modulator, and

4 is a signal point layout converter.

Attorney: Sadakazu Igeta, patent attorney

Fig. 1 Block diagram of an embodiment of the invention.

1 Differential-rotation object encoder

3 Modulator

4 Signal point layout converter

11 Differential encoder

12 Rotation object encoder

Fig. 2 Signal point layout of Fig. 1.

Fig. 3 Block diagram of a conventional example.

3 Modulator

11 Differential encoder

12 Rotation object encoder

Fig. 4 Signal point layout of Fig. 3.

Number of errors when crossing quadrants